Journal of Vocational Health Studies 08 (2025): 217-223

Journal of Vocational Health Studies

https://e-journal.unair.ac.id/JVHS

LABORATORY WASTEWATER TREATMENT USING MICROBIAL FUEL CELL: A FUTURE PARADIGM OF SUSTAINABILITY

PENGOLAHAN AIR LIMBAH LABORATORIUM MENGGUNAKAN SEL BAHAN BAKAR MIKROBA: PARADIGMA MASA DEPAN KEBERLANJUTAN

Literature Review
Studi Literatur

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ABSTRACT

Background: *In Southwestern Bangladesh, the absence of safe drinking water is a severe catastrophe. Coastal inhabitants were pressured to drink saline water and were not able to fetch conveyable drinking water. The Incremental Lifetime Cancer Risk value for Cr, Ni, Cd of mine area of Dinajpur, Hazaribagh tannery, Singair, Manikgonj, Rajshahi city and Chuadanga is found from* 18.2×10^{-3} *to* 1.32×10^{-3} *where more than* 1×10^{-4} *is considered significant. At present the global burden of excreta-related syndrome is enormously high. Therefore, laboratory wastewater treatment is an urgent need.* ***Purpose:*** *A microbial fuel cell can be considered a sustainable tool to mitigate this problem. The findings of this study will help the reader to know that biotechnology in the laboratory is a self-sustaining wastewater treatment method. Future direction is also anticipated. Moreover, people will be able to understand the wise use of water.* ***Review:*** *It was a descriptive type of qualitative study with a literature review. The literature research was performed electronically through Springer, PubMed, Google Scholar and distinctive databases. The literature published between 2013 - 2024 was searched to identify the relevant literature using the keywords: "Microbial fuel cells," "sustainability," "wastewater," "saline water," and "Bangladesh."* ***Result:*** *This study explored different studies related to the existing mechanism of MFC in wastewater treatment. The paper highlighted remarkable research from 2016 to 2024 as well as challenges and solutions to these challenges in scaling up MFC.* ***Conclusion:*** *The author strongly recommends that laboratory wastewater treatment by microbial fuel cells is a paradigm of sustainability for its capability of low sludge production results in a reduction of secondary pollution and low carbon footprint arising from less fossil-related* CO_2 *production as a result of low energy consumption. A lot more work is essential in the field to produce a sustainable energy source in countries like Bangladesh.*

ARTICLE INFO

Received 15 May 2024
Revised 15 May 2024
Accepted 24 January 2025
Available Online 21 March 2025

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Keywords:
Bangladesh, Microbial fuel cells, Saline water, Sustainability, Wastewater

ABSTRAK

Latar belakang: Di Bangladesh Barat Daya, tidak adanya air minum yang aman merupakan bencana yang parah. Penduduk pesisir ditekan untuk minum air asin dan tidak dapat mengambil air minum yang dapat diangkut. Nilai risiko kanker seumur hidup tambahan untuk Cr, Ni, Cd di area tambang Dinajpur, penyamakan kulit Hazaribagh, Singair, Manikgonj, kota Rajshahi, dan Chuadanga ditemukan dari 18.2×10^{-3} hingga 1.32×10^{-3}, di mana lebih dari 1×10^{-4} dianggap signifikan. Jadi, pengolahan air limbah laboratorium merupakan kebutuhan mendesak. **Tujuan:** Sel bahan bakar mikroba dapat dianggap sebagai alat yang berkelanjutan untuk mengurangi masalah ini. Temuan penelitian ini akan membantu pembaca untuk mengetahui bahwa bioteknologi di laboratorium merupakan metode pengolahan air limbah yang mandiri. Arah masa depan juga diantisipasi. Selain itu, orang-orang akan dapat memahami penggunaan air yang bijaksana. **Telaah pustaka:** Penelitian kualitatif deskriptif dengan tinjauan pustaka. Penelitian pustaka dilakukan secara elektronik melalui Springer, PubMed, Google Scholar, dan basis data khusus. Literatur yang diterbitkan antara tahun 2013 - 2024 untuk mengidentifikasi literatur yang relevan menggunakan kata kunci: "Sel bahan bakar mikroba", "keberlanjutan", "air limbah", "air garam", dan "Bangladesh" ditelusuri. **Hasil:** Penelitian ini mengeksplorasi berbagai penelitian yang terkait dengan mekanisme MFC yang ada dalam pengolahan air limbah. Makalah ini menyoroti penelitian luar biasa dari tahun 2016 hingga 2024 serta tantangan dan solusi untuk tantangan ini dalam meningkatkan MFC. **Kesimpulan:** Penulis sangat menyarankan bahwa pengolahan air limbah laboratorium dengan sel bahan bakar mikroba merupakan paradigma keberlanjutan karena kemampuannya menghasilkan produksi lumpur rendah yang menghasilkan pengurangan polusi sekunder dan jejak karbon rendah yang timbul dari lebih sedikit produksi CO_2 terkait fosil sebagai akibat dari konsumsi energi yang rendah. Masih banyak pekerjaan yang penting di lapangan untuk menghasilkan sumber energi berkelanjutan di negara-negara seperti Bangladesh.

Kata kunci:
Bangladesh, Sel bahan bakar mikroba, Air garam, Keberlanjutan, Air limbah

Journal of Vocational Health Studies p-ISSN: 2580–7161; e-ISSN: 2580–717x
DOI: 10.20473/jvhs.V8.I3.2025.217-223

INTRODUCTION

Laboratory wastewater is the outcome of chemical remnants utilized at the time of research. Despite its small quantity, it poses a genuine effect on the environment. The wastewater of a laboratory is composed of iron (Fe), zinc (Zn), copper (Cu), chromium (Cr), lead (Pb), etc. These heavy metals are threatening both the sustainable environment and humans. Cancer risk for Pb, Cd, Ni, and Cr consumption over ingesting groundwater is found to exist in numerous places (Parvin *et al*., 2022).

Laboratory wastewater not only contains heavy metals, antibiotics, and a high pH but also increases chemical oxygen demand, biological oxygen demand, total suspended solid, and total dissolved solid (Agustina *et al*., 2022). The rest of the diverse antibiotics such as ciprofloxacin, clarithromycin, amoxicillin, clindamycin, lincomycin, linezolid, metronidazole, moxifloxacin, nalidixic acid, and sulfa pyridine were present in the surface waters of Matlab of Chandpur and Dhaka City. Among these, ciprofloxacin (1407 ng/L) and clarithromycin (909 ng/L) were identified in maximum concentration in the water (Angeles *et al*., 2020).

Frequently used antibiotics in microbiology laboratories like ciprofloxacin, vancomycin, nalidixic acid, and kanamycin are considered high-risk waste (Parvin *et al*., 2022) and thus cannot be inactivated through physical treatment methods. Unlimited expenditure of antibiotics for prophylactic determinations raises the risk of increasing antimicrobial resistance in the marine environment (Chowdhury *et al*., 2022). Wastewater, like reservoirs, provides an optimum environment for antimicrobial resistance genes to exist. At present the global burden of excreta-related syndrome is enormously high. So, laboratory wastewater treatment is an urgent need (Mara, 2013; Samal *et al*., 2022). High manufacturing costs, significant investment in maintenance, specialized personnel, lab personnel adaptation to the technology, space constraints, installation difficulties, maintaining them in a spreadsheet database, and maintaining living organisms while lack of optimum condition leads to bacterial death are challenging for developing countries with limited financial resources.

The rapidly increasing population and industrial expansion have been raising global water demand by 1% each year also the published report to face a decline in water insufficiency by 2050 is alarming (Shekhawat *et al*., 2023). Coastal inhabitants were pressured to drink saline water and were not able to fetch conveyable drinking water because of the scarcity of accessible, secured water sources in Bangladesh. Approximately 80% of infections in developing countries are accredited to unsafe drinking water and waterborne illnesses. In Southwestern Bangladesh, absence of safe drinking water is a severe catastrophe (Abedin *et al*., 2019). Owing to seawater interruption, appropriate drinking water is insufficient in southwest coastal Bangladesh. Parvin *et al*. (2022) calculated hazard quotient (HQ) and *Incremental Lifetime Cancer Risk* (ILCR) for consumption of heavy metal through drinking the groundwater of different regions of Bangladesh. The HQ for Cr (1.14) and Pb (12.23) in the groundwater of Manikgonj and Rajshahi City indicating significant, where HQ > 1 means adverse non-carcinogenic health risk. The ILCR value for Cr, Ni, Cd of mine area of Dinajpur, Hazaribagh tannery, Singair, Manikgonj, Rajshahi City and Chuadanga is found from 18.2×10^{-3} to 1.32×10^{-3}. ILCR $>1 \times 10^{-4}$ is considered significant. The concentration of pb and Cr in Buriganga River was respectively 0.119 mg/L and 0.119 mg/L. Bangshi River contained 0.108 mg/L Pb. The concentration of Cr (VI) is greater in Balu River (1.02 mg/L) compared to the permissible level 0.1 mg/L. The iron (Fe) concentrations were 2 – 9 mg/L in Teesta river basin and coal mine area of Dinajpur, which indicates that it is higher. Pb poisoning may cause anemia, weakness, kidney and brain damage. Cd and Cr (VI) are extremely toxic and carcinogenic. Excess uptake of Fe and Mn through water results in Parkinson disease, diabetes mellitus, cardiovascular disease, kidney, liver, and neurological disorders (Parvin *et al*., 2022). So, wastewater discharge requires immediate attention.

Microorganisms are capable of surviving extreme conditions by digesting complex contaminants which is prospective for environmental pollution bioremediation. Municipal solid waste rejected fractions of bacterial conglomerates have enough symbiotic structure as directed by electrons released in corresponding with substrate decomposition (Kamel *et al*., 2020).

A microbiological fuel cell can be considered as a sustainable tool to mitigate this problem (Srimongkol *et al*., 2022; Thapa *et al*., 2022). *Microbial Fuel Cell* (MFC) is an environmentally friendly technology (Cao *et al*., 2019). MFC has been evidenced before pharmaceutical and hospital wastewater treatment (Thapa *et al*., 2022). The findings of this study will help the reader to know that biotechnology in the laboratory is a self-sustaining wastewater treatment method (Leicester *et al*., 2023; Malik *et al*., 2023). The building and investigation of MFCs necessitates knowledge ranging from microbiology, and electrochemistry to materials and environmental engineering (Parkash, 2016). Moreover, people will be able to understand the wise use of water.

LITERATURE REVIEW

Search strategy

This was a descriptive type of qualitative study with a literature review. The literature research was performed electronically through Springer, PubMed, Google Scholar and distinctive databases. To identify the relevant literature published between 2013 - 2024 the keywords: "Microbial fuel cells," "sustainability," "wastewater," "saline water," and "Bangladesh" were searched.

Data extraction

Based on literature searches, there were several related articles. After filtering out the titles and abstracts, many were excluded because they did not fit the inclusion criteria that the study used. The authors reviewed the full text of the remaining 25 studies for a more detailed evaluation. The inclusion criteria included full articles, with the topic of microbial fuel cells published in the 2013 – 2024 range, articles published by English-language international journals with DOI (Figure 1).

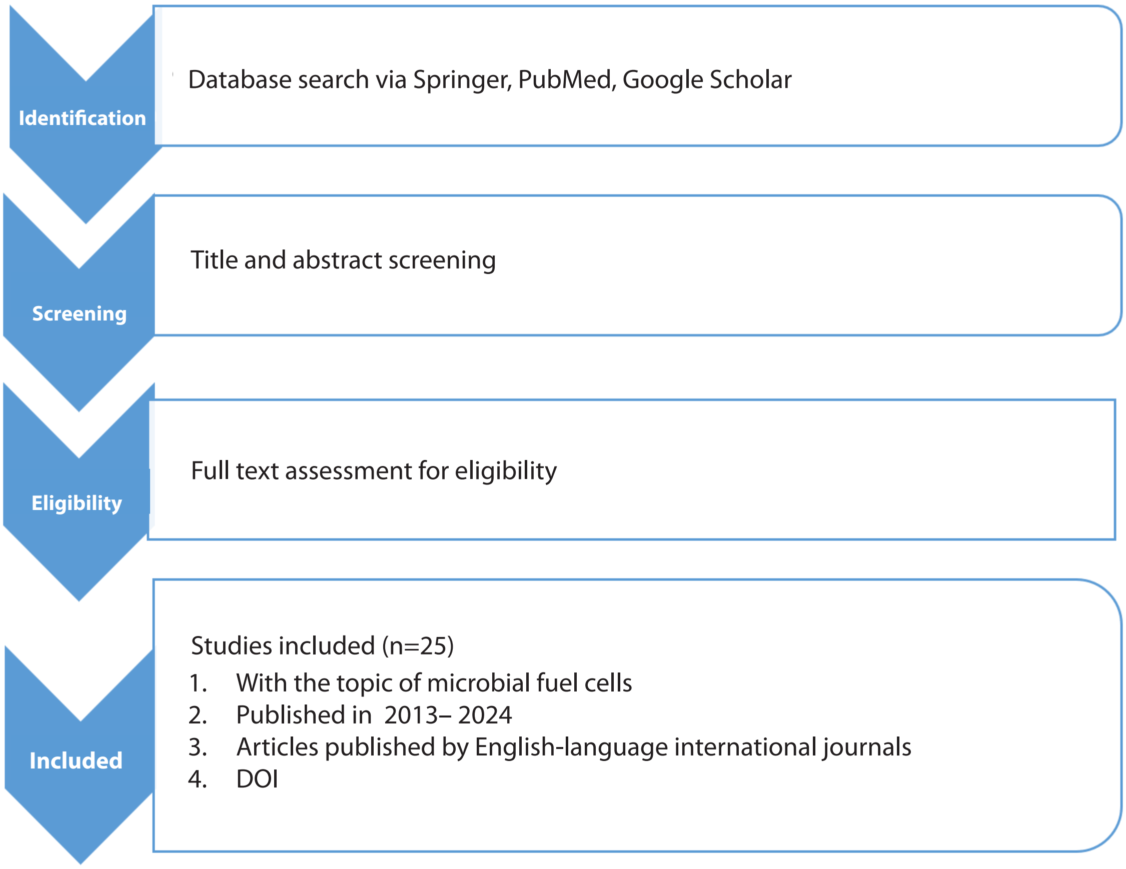

Figure 1. Literature selection process

RESULT

Mechanism of MFCS in wastewater treatment

Microbial Fuel Cell (MFC) performance is based on the surface area of the anode or cathode can be seen in Figure 2. The anode should be non-toxic to microorganisms and chemically inert. The anode consists of a wide surface area to allow for bacterial adherence and high electrical conductivity to smooth the transmission of charge, as well as enhanced current collection competency. Anode surface area is crucial in the development and sustaining of bio-catalytic action. It can be changed to enhance its suitability for microorganisms.

Factors affecting performances of MFCs during wastewater treatment

Microbial Fuel Cell (MFC) performance are determined by microbial electron transfer, fuel oxidation, oxygen supply, circuit resistance, proton transfer via the membrane, reduction at the cathode site, concentration, and pH. These factors can be modified over time for better output.

Electrode properties

Electrode material possessions stimulus electrode performance and power productivity. However, because of the high-power output per unit surface area, graphite felt, carbon cloth, carbon felt, carbon mesh, and graphite fiber brush are used as electrodes. Furthermore, reports on platinum (Pt)-based cathodes and bio cathodes suggest a rise in MFCs' power involvement by accumulative catalytic activity consuming oxygen or falling over potential but not economically friendly. The performance of the cathode electron receiver defines the voltage density in MFCs. In MFC, protonic generations arise at an anodic end with the easing of smooth graceful electrons to co-operate with the oxygen molecule for the construction of water. Anode acidification happens owing to the non-stop loop operation due to inadequate proton transport over the membrane. The cathode is alkalized owing to the minor efficiency of proton replacement. These constraints eventually hinder the effectiveness of MFCs, resulting in a pH concentration gradient. An increase in the pH of the cathode section decreases current production, thus lowering the working pH required to accomplish advanced power production.

Temperature

Temperature also has a considerable impact on MFCs' performance in terms of re-moving COD. MFCs' kinetic properties and thermodynamic properties are highly dependent on temperature. Rise in temperature results in a rise in the power compactness but a reduction in the ohmic resistance. The properties of a change in temperature on the electrode potential, COD removal has been examined. As the interior resistance of the MFC increases, the power density developed is instantaneously reduced. MFCs are capable of operating at a wide range of temperatures.

Aeration

Aeration, along with the presence of oxygen in the cathode, is another key characteristic of MFC function, since organic catalysts such as Pt, iron, and Al are known to require huge amounts of oxygen to transport the reduction process as the electron acceptor of the cathode. An air-purging pump is compulsory in the cathode; this technique increases the cost of an MFC. Diverse aeration rates were used to estimate the efficacy of MFCs. To learn the effect of anode aeration on electricity generation, an air-cathode MFC that had earlier been embroidered anaerobically in the anode was exposed to aeration spasmodically and steadily, power generation was amplified dramatically in the anode MFC for aeration. The aeration flow rate also plays an important role in bioelectricity generation. To improve MFCs' performance through introducing significant efforts in the investigation of separators, electrode materials, design of the reactor, and various methods to analyze wastewater are applied.

This study explored different studies related to the existing mechanism of MFC in wastewater treatment. The results showed that wastewater treatment using microbial fuel cells is still at the laboratory scale. The paper highlighted remarkable research from 2016 to 2024 (Table 1) as well as challenges and solutions to these challenges in scaling up MFC (Figure 3). The findings of this study through comprehensive literature analysis show that scaling up of MFC not only reduces carbon footprint but also ensures direct recovery of electric energy, value-added products, good effluent quality, and low sludge production (Figure 4). Biotechnology in the laboratory is a self-sustaining wastewater treatment method.

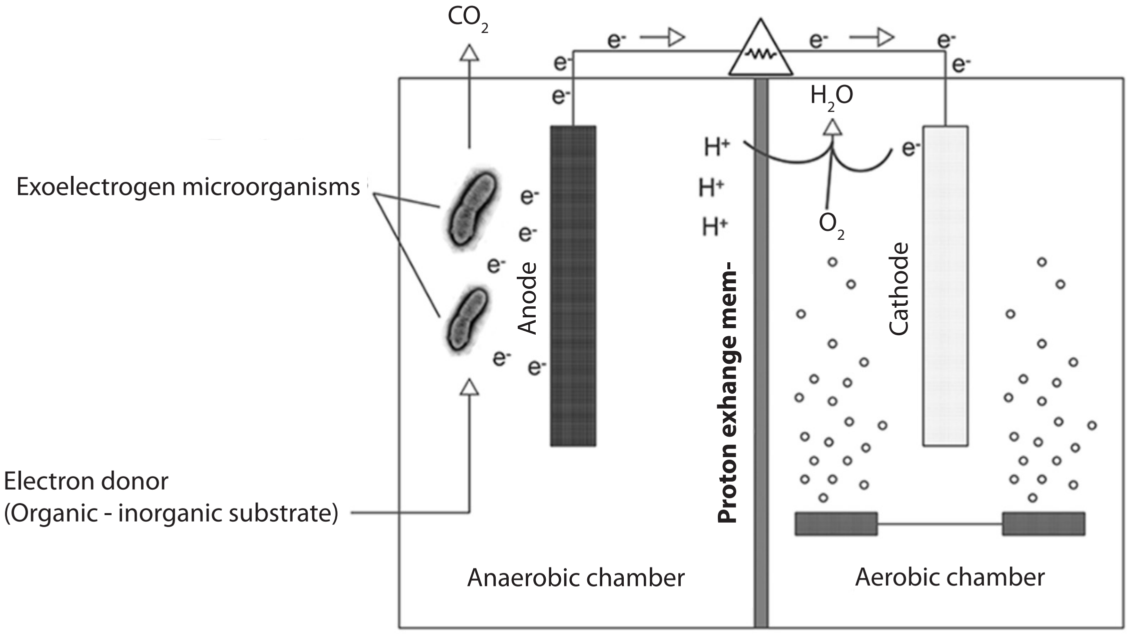

Figure 2. Microbial Fuel Cell (https://www.frontiersin.org/files/Articles/248548/fmicb-08-00643-HTML/image_m/fmicb-08-00643-g001.jpg)

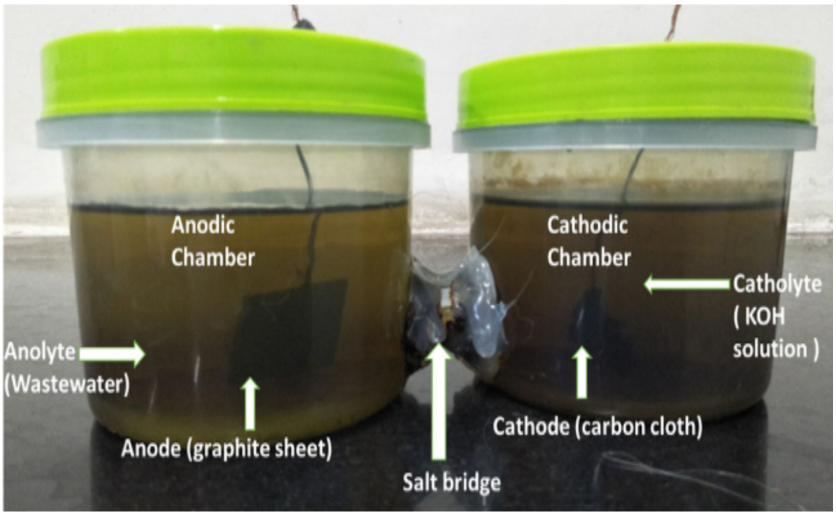

Figure 3. Microbial fuel cells (https://g.co/about/etkeqz)

Table 1. Notable research that deliberated wastewater treatment through *Microbial Fuel Cell* (MFC)

Year	Suggestions by the authors	Reference
2016	The authors stated that refining the overall act of MFC will assist in the treatment of wastewater.	Chaturvedi and Verma, 2016
2018	Authors claim that MFCs consume existing microorganisms in the waste as a catalyst to produce electricity and function as a wastewater treatment unit itself. Selective mixed culture is identically likely to do so due to the good outcome on COD removals. The accumulation of *Gram-negative* bacteria declines COD and BOD levels by 29.32% and 51.32%.	Arbianti *et al.*, 2018
2019	Authors conclude that wastewater can be straight engaged as the inoculum for MFCs. MFC could be used for smart alternative in wastewater treatment.	Cao *et al.*, 2019
2020	Authors provide an update on MFC-based wastewater treatment with energy harvesting research and analyses numerous biocatalysts' fundamental mechanisms in pollutant exclusion thus energy regaining from wastewater.	Guo *et al.*, 2020
2024	This paper claims that the prospective *Pseudomonas* strain was estimated as an attractive aspirant to generate electricity in MFC with oily wastewater being the fuel at 43.625 mg/L preliminary chemical oxygen demand (COD). COD removal was 83.6 ± 0.1%.	Varnava *et al.*, 2024

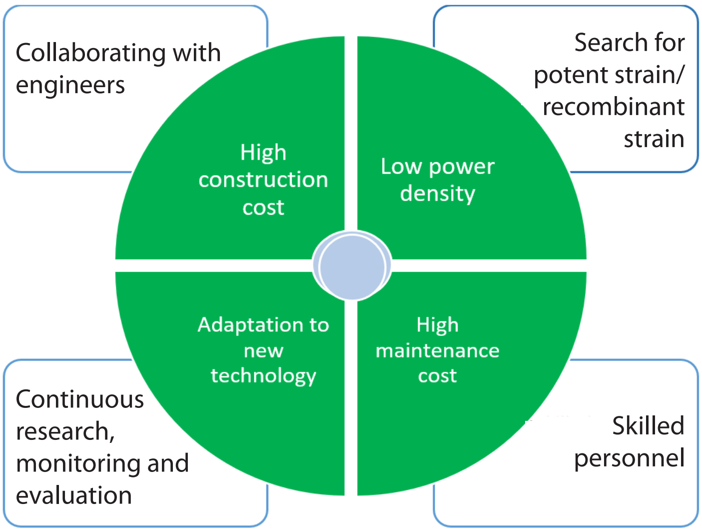

Figure 4. Challenges and solutions to the challenge in scaling up *Microbial Fuel Cell* (MFC)

DISCUSSION

Non-renewable energy sources are reducing and renewable energy sources are not accurately applied. There is an immediate requisite for the search for alternate routes for energy generation. Numerous studies have documented new visions into microbial fuel cells (Table 1) (Chaturvedi and Verma, 2016; Malik *et al*., 2023). It has the potential to extravagance wastewater with bioelectricity production instantaneously. The practicability of wastewater treatment by microbial fuel cells is amplified because high-value derivatives like heavy metals are found. It reduces the dependence on chemicals for precipitating these products (Nawaz *et al*., 2022). The contaminants of wastewater are reduced by an ordinary treatment method at a laboratory scale (Dhote *et al*., 2014).

Biological treatment for the elimination of various pharmaceutical contaminants from wastewater ought to be massively researched as those are environmentally sustainable (Samal *et al*., 2022). Similar evidence was found by Srimongkol *et al*. (2022) who showed that biological systems are not only cost-effective but also environmentally friendly compared to physical and chemical systems.The physical besides physical-chemical methods do not eradicate contaminants, but hand over them from one stage to another (Xu *et al*., 2022).

A *Microbial Fuel Cell* (MFC) is a gadget where microorganisms ingest organic compounds for nutrients and release electrons in the electrode. Microbial fuel cells utilize wastewater as a substrate (Pant *et al*., 2010). After the inoculation of microbes into the water, microbes play a dual role, not only for electricity generation but also for wastewater treatment.

Expanding MFC to eliminate pollutants in wastewater is still at the laboratory scale (Parkash, 2016; Guo *et al*., 2020). Laboratory scale methods have delivered vital information on various wastewater solicitations. To develop MFCs capable of treating highly dynamic wastewaters, significant pilot test systems need to be built earlier for effective commercialization (Sonar *et al*., 2021).

The enhancement of structural stability for long-term action remains a significant issue for field solicitations. The arrangement of the technology with other applications can actualize the vision of a possible significant inauguration of MFC (Cao *et al*., 2019). *Gram-negative* organisms result in better COD removal than gram-positive organisms along with better adaptation ability (Arbianti *et al*., 2018). *Pseudomonas* strain work as redox mediator in MFC. The prospective of *Pseudomonas* strain was estimated as an attractive aspirant with 83.6 ± 0.1% COD removal capability (Varnava *et al*., 2024). Saha *et al*. (2019) identified *Pseudomona*s strain as potential electro genic bacteria of MFC. Application of this frequently available electro genic bacteria is expected to lead to a future paradigm of self-sustainability.

CONCLUSION

The author strongly recommends that laboratory wastewater treatment by microbial fuel cells is a paradigm of sustainability for its capability of low sludge production results in a reduction of secondary pollution and low carbon footprint arising from less fossil-related CO_2 production as a result of low energy consumption. However, research entitled "*Pseudomonas aeruginosa*: An eco-friendly tool of MFC in the laboratory wastewater treatment" will be conducted in the future. Moreover, there is an urgent need for the implementation of specific guidelines on the discharge of untreated laboratory wastewater. A lot more work is essential in the field to produce a sustainable energy source in countries like Bangladesh.

ACKNOWLEDGMENTS

The author would like to thank to data sources. The author has no conflicts of interest to declare.

REFERENCE

Abedin, Md.A., Collins, A.E., Habiba, U., Shaw, R., 2019. Climate Change, Water Scarcity, and Health Adaptation in Southwestern Coastal Bangladesh. International Journal of Disaster Risk Science Vol. 10(1), Pp. 28-42.

Agustina, T.E., Rachman, S., Ilmi, N., Pranajaya, V., Gayatri, R., 2022. Treatment of Laboratory Wastewater by Using Fenton Reagent and Combination of Coagulation-Adsorption as Pretreatment. Journal of Ecological Engineering Vol. 23(8), Pp. 211-221.

Angeles, L.F., Islam, S., Aldstadt, J., Saqeeb, K.N., Alam, M., Khan, M.A., Johura, F.-T., Ahmed, S.I., Aga, D.S., 2020. Retrospective Suspect Screening Reveals Previously Ignored Antibiotics, Antifungal Compounds, and Metabolites in Bangladesh Surface Waters. The Science of the Total Environment Vol. 712, Pp. 136285.

Arbianti, R., Utami, T.S., Leondo, V., Elisabeth, Putri, S.A., Hermansyah, H., 2018. Effect of Biofilm and Selective Mixed Culture on Microbial Fuel Cell for The Treatment of Tempeh Industrial Wastewater. IOP Conference Series: Materials Science and Engineering Vol. 316(1), Pp. 012073.

Cao, Y., Mu, H., Liu, W., Zhang, R., Guo, J., Xian, M., Liu, H., 2019. Electricigens in The Anode of Microbial Fuel Cells: Pure Cultures Versus Mixed Communities. Microbial Cell Factories Vol. 18(1), Pp. 39.

Chaturvedi, V., Verma, P., 2016. Microbial Fuel Cell: A Green Approach for The Utilization of Waste for The Generation of Bioelectricity. Bioresources and Bioprocessing Vol. 3(1), Pp. 38.

Chowdhury, S., Rheman, S., Debnath, N., Delamare-Deboutteville, J., Akhtar, Z., Ghosh, S., Parveen, S., Islam, K., Islam, Md.A., Rashid, Md.M., Khan, Z.H., Rahman, M., Chadag, V.M., Chowdhury, F., 2022. Antibiotics usage Practices in Aquaculture in Bangladesh and Their Associated Factors. One Health Vol. 15, Pp. 100445.

Dhote, J., Chavhan, Dr.A., Sangita, I., 2014. Design of Laboratory Based Waste Water Treatment Plant. International Research Journal of Science and Engineering Vol. 2(3), Pp. 104-111.

Guo, Y., Wang, J., Shinde, S., Wang, X., Li, Y., Dai, Y., Ren, J., Zhang, P., Liu, X., 2020. Simultaneous Wastewater Treatment and Energy Harvesting in Microbial Fuel Cells: An Update on The Biocatalysts. RSC Advances Vol. 10(43), Pp. 25874-25887.

Kamel, M.S., Abd-Alla, M.H., Abdul-Raouf, U.M., 2020. Characterization of Anodic Biofilm Bacterial Communities and Performance Evaluation of A Mediator-Free Microbial Fuel Cell. Environmental Engineering Research Vol. 25(6), Pp. 862-870.

Leicester, D.D., Settle, S., McCann, C.M., Heidrich, E.S., 2023. Investigating Variability in Microbial Fuel Cells. Applied and Environmental Microbiology Vol. 89(3), Pp. e02181-22.

Malik, S., Kishore, S., Dhasmana, A., Kumari, P., Mitra, T., Chaudhary, V., Kumari, R., Bora, J., Ranjan, A., Minkina, T., Rajput, V.D., 2023. A Perspective Review on Microbial Fuel Cells in Treatment and Product Recovery from Wastewater. Water Vol. 15(2),Pp. 316.

Mara, D., 2013. Domestic Wastewater Treatment in Developing Countries. Routledge, London.

Nawaz, A., ul Haq, I., Qaisar, K., Gunes, B., Raja, S.I., Mohyuddin, K., Amin, H., 2022. Microbial Fuel Cells: Insight into Simultaneous Wastewater Treatment and Bioelectricity Generation. Process Safety and Environmental Protection Vol. 161, Pp. 357-373.

Pant, D., Van Bogaert, G., Diels, L., Vanbroekhoven, K., 2010. A Review of The Substrates used in Microbial Fuel Cells (MFCs) for Sustainable Energy Production. Bioresource Technology Vol. 101(6), Pp. 1533-1543.

Parkash, A., 2016. Microbial Fuel Cells: A Source of Bioenergy. Journal of Microbial & Biochemical Technology Vol. 8(3), Pp. 247-255.

Parvin, F., Haque, M.M., Tareq, S.M., 2022. Recent Status of Water Quality in Bangladesh: A Systematic Review, Meta-Analysis and Health Risk Assessment. Environmental Challenges Vol. 6, Pp. 100416.

Saha, T., Protity, A., Zohora, F., Shaha, M., Ahmed, I., Barua, E., Sarker, P.K., Mukharjee, S., Barua, A., Salimullah, M., Hashem, A., 2019. Microbial Fuel Cell (MFC) Application for Generation of Electricity from Dumping Rubbish and Identification of Potential Electrogenic Bacteria Adv Ind Bio- Technol 2: 010. Advances in Industrial Biotechnology Vol. 2(1).

Samal, K., Mahapatra, S., Hibzur Ali, M., 2022. Pharmaceutical Wastewater as Emerging Contaminants (EC): Treatment Technologies, Impact on Environment and Human Health. Energy Nexus Vol. 6, Pp. 100076.

Shekhawat, S.S., Saini, P., Upadhyay, A., Pareek, N., Arora, S., Gupta, A.B., Vivekanand, V., 2023. Treatment of Clinical Laboratory Sewage using A Decentralized Treatment Unit and Risk Reduction for Its Reuse in Irrigation using Hybrid Disinfection. Journal of Environmental Management Vol. 144, Pp.118684.

Sonar, I., Agrawal, K., Mangudkar, R., Damodare, H.,Sshaikh, Salman, Ahire, T., 2021. Application of Microbial Fuel Cell (MFC) in Wastewater Treatment. College of Engineering, Pune (An Autonomous Institute of Government of Maharashtra), India.

Srimongkol, P., Sangtanoo, P., Songserm, P., Watsuntorn, W., Karnchanatat, A., 2022. Micoalgae-Based Wastewater Treatment for Developing Economic and Environmental Sustainability: Current Status and Future Prospects. Frontiers in Bioengineering and Biotechnology Vol. 10, Pp. 904046.

Thapa, B.S., Pandit, S., Patwardhan, S.B., Tripathi, S., Mathuriya, A.S., Gupta, P.K., Lal, R.B., Tusher, T.R., 2022. Application of Microbial Fuel Cell (MFC) for Pharmaceutical Wastewater Treatment: An Overview and Future Perspectives. Sustainability Vol. 14(14), Pp. 8379.

Varnava, C.K., Persianis, P., Ieropoulos, I., Tsipa, A., 2024. Electricity Generation and Real Oily Wastewater Treatment by Pseudomonas Citronellolis 620C in A Microbial Fuel Cell: Pyocyanin Production as Electron Shuttle. Bioprocess and Biosystems Engineering Vol. 47(6), Pp. 903-917.

Xu, W., Zou, R., Jin, B., Zhang, G., Su, Y., Zhang, Y., 2022. The Ins and Outs of Pharmaceutical Wastewater Treatment by Microbial Electrochemical Technologies. Sustainable Horizons Vol. 1, Pp. 100003.